Carbon Pricing and Monetary Policy in an Estimated Macro-Climate Model*

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Abstract

I develop and estimate a two-agent New Keynesian (TANK) macro-climate model with energy to study the effects of carbon price shocks on the euro area economy. Using EU Emissions Trading System data, I document three features of such shocks: a gradual decline in emissions, a temporary surge in headline inflation, and a contraction in economic activity. The model captures these dynamics through adjustment costs in fossil energy use, limited substitutability between fossil and green energy, and strong complementarities between energy and other inputs. Hand-to-mouth households play an important role, as they are particularly vulnerable to higher energy prices. The estimated model suggests that optimal monetary policy prioritizes output stabilization at the cost of temporarily higher inflation in response to the shock. A Taylor rule targeting core rather than headline inflation mitigates GDP losses and approximates the welfare-optimal response.

JEL Codes: E52,H23,Q43,Q58

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1 Introduction

As climate change becomes an increasingly pressing global challenge, governments are implementing ambitious policies to accelerate the transition to a low-carbon economy, most notably through carbon pricing. In response, a growing literature has emerged that incorporates environmental dynamics into DSGE frameworks to study the macroeconomic implications of such policies (see for instance Annicchiarico and Di Dio (2015), Diluiso et al. (2021), Coenen et al. (2024), Sahuc et al. (2025)). However, substantial uncertainty remains about how carbon price increases affect key macroeconomic variables, especially in the context of rising concerns about "greenflation" — the inflationary pressure stemming from higher energy costs (Schnabel, 2022). To effectively design and evaluate monetary policy responses to macroeconomic dynamics caused by carbon policy initiatives, it is crucial to develop models that closely align with the empirical responses to carbon pricing.

In this paper, I develop and estimate a two-agent New Keynesian macro-climate model with energy that accounts for macroeconomic effects of carbon price increases in the euro area observed in the data. I assess the macroeconomic impact of carbon price increases on the EU Emission Trading System (EU ETS) carbon market using local projections. For this I use the carbon price shock series constructed by Känzig (2023), which identifies unexpected changes in ETS emission allowance future prices. My findings suggest that carbon price shocks effectively reduce GHG emissions, though the reduction is not immediate. Instead, emissions decline gradually, likely due to technological constraints and infrastructure limitations that prevent an instantaneous shift away from fossil energy. However, the emission reduction comes at an economic cost for the euro area. The carbon price shock triggers a sharp increase in energy prices, which is then passed on to consumer prices, leading to an immediate rise in headline inflation. Higher energy costs raise production expenses for firms and increase households' energy bills, causing a decline in economic activity. The fall in wages, stemming from firms' higher energy-related costs, further reduces household income, amplifying the drop in consumption and aggregate demand. This downturn is potentially exacerbated by monetary policy tightening, as central banks respond to inflationary pressures by raising interest rates.

To accurately capture these empirical dynamics, I estimate my model using Bayesian impulse response matching. This methodology involves minimizing the distance between the dynamic responses of my model to a carbon price shock and analog objects in the data obtained from the local projections. My model accounts well for the key features of the estimated impulse response functions: a gradual decline in emissions, an immediate surge in headline inflation and a significant drop in economic activity. The following parameter specifications are key features for the success of the model fit:

The first non-standard feature of my model is the introduction of quadratic adjustment costs for fossil energy producers, preventing an immediate reduction in fossil energy use following a carbon price shock. The posterior mode of the adjustment cost parameter suggests that these costs are significantly positive. These frictions reflect real-world technological constraints and infrastructure limitations, ensuring that the delayed decline in emissions observed in the data is replicated in the model. Second, the estimated elasticity of substitution between green and fossil energy is below unity in my model, indicating that these energy sources are complements rather than substitutes. This contrasts with much of the literature, where substitution elasticities typically range between 1.8 and 3. The low substitutability in response to temporary shocks in my model is essential to capturing the strong pass-through from fossil energy prices to aggregate energy prices. Higher substitutability would imply a weaker inflationary response, leading to an underestimation of the observed rise in consumer prices and the associated decline in aggregate demand. Third, there is very strong complementarity of energy in production and consumption. The model assumes that energy is a crucial input for both firms and households, making it difficult to substitute away from energy consumption. This amplifies the economic effects of carbon price shocks, as it makes households and firms more vulnerable to higher energy prices following carbon price shocks. Finally, including hand-to-mouth households into the model helps explaining the significant drop in consumption observed in the data, because they are more vulnerable to energy price increases.

To conduct meaningful policy analysis, it is crucial to use a model that captures the macroeconomic transmission of carbon price shocks. I analyze the role of monetary policy in mitigating the economic costs of such shocks. I compare the implications of a welfare-maximizing Ramsey policy with alternative interest rate rules in response to a carbon price shock. The results highlight a key trade-off for monetary policy: stabilizing inflation would require higher interest rates, but this would amplify the contraction in aggregate demand. The Ramsey planner instead places greater weight on stabilizing real activity, lowering interest rates and accepting temporarily higher inflation to cushion the decline in demand. A Taylor rule that stabilizes core instead of headline inflation comes closer to this optimal response. By focusing on core inflation, the central bank effectively "looks through" the temporary surge in energy inflation, avoiding excessive monetary tightening and thus mitigating the fall in demand. While this approach leads to a somewhat larger initial increase in headline inflation, this effect is small and not persistent. In contrast, the mitigation of GDP losses is substantial, making core inflation targeting a welfare-improving policy choice.

This paper contributes to the growing macro-climate DSGE literature by providing an empirically grounded framework for evaluating the macroeconomic effects of carbon pricing in the euro area. The findings are particularly relevant for the design of monetary policy in the face of inflationary pressures and output losses arising from climate policy initiatives.

Related Literature. This papers contributes to both empirical and theoretical literature on the macroeconomic effects of climate change mitigation policies and potential implications for monetary policy. First, my paper is related to a growing strand of empirical literature assessing the macroeconomic effects of carbon price increases. The empirical part is closely related to Känzig (2023). Känzig uses high-frequency identification of regulatory events on the European carbon market to construct a carbon policy surprise shock series and study the effects on the euro area economy and on emissions. His findings suggest that an increase in the EU ETS carbon price is effective in reducing emissions, but entails economic costs as it creates inflationary pressures and a fall in employment and real activity. Metcalf and Stock (2023) analyze the macroeconomic implications of European carbon taxes. Interestingly, they find that while carbon taxes reduce emissions, they do not lead to a significant reduction in GDP. Similarly, Konradt and Weder di Mauro (2023) do not find evidence for significant inflationary pressures caused by carbon taxes using data from European and Canadian carbon tax regimes.

I contribute to this literature by assessing the impact of EU ETS carbon price increases on emissions and the macroeconomy and using these results to estimate a New Keynesian macro-climate model with energy using Bayesian impulse response matching. Gagliardone and Gertler (2023) use a similar methodology to estimate a model to match the impulse responses to an oil shock. Their findings suggest that strong complementarity of oil in production and consumption are key to account for the macreconomic dynamics following an oil price increase. Sahuc et al. (2025) estimate a simple New Keynesian climate model without an explicit energy sector to analyze long-term transition scenarios under different climate policy regimes.

The second related strand of literature focuses on developing New Keynesian models with energy to assess the impact of carbon price increases on inflation and the conduct of monetary policy. Coenen et al. (2024) extend the ECB's New Area-Wide Model with a disaggregated energy sector to assess the impact of different carbon transition paths on the euro area economy. Their results suggest an increase in headline inflation and a fall in aggregate demand during the transition due to the increase in energy prices. Similarly, Olovsson and Vestin (2023) find that it is optimal for euro area monetary policy to see through increasing energy prices and focus on stabilizing core inflation, which leads to an increase in headline inflation. However, their results suggest that this increase is modest as long as the carbon tax path is pre-announced. Del Negro et al. (2023) develop a two-sector model to study how the green transition affects the central bank's trade-off between keeping prices stable and closing the output gap. Nakov and Thomas (2023) study Ramsey optimal monetary policy in a model with climate externalities and how it is affected by different environmental policy regimes. I estimate a model with energy that is able to account for the gradual response in emissions, inflationary pressures and the significant fall in economic activity following a carbon price shock to assess the implications of climate change mitigation for the macroeconomy and monetary policy.

Structure. The remainder of the paper is structured as follows: Section 2 presents empirical evidence on the macroeconomic effects of a carbon price shock in the euro area. Section 3 introduces the New Keynesian macro-climate model with energy. Section 4 outlines the estimation methodology, presents the results and discusses key parameter specifications. Section 5 evaluates the impact of alternative monetary policy rules on the macroeconomic implications of carbon price shocks. Section 6 concludes.

2 Empirical Analysis

In this section, I assess the macroeconomic implications of an increase in the EU ETS carbon price in the euro area. The EU ETS operates as a carbon market where a fixed number of emission allowances are issued, granting firms the right to emit greenhouse gases (GHGs) into the atmosphere. Firms can buy, sell, and trade these allowances, creating a market-driven price for carbon emissions. To identify changes in the ETS price, I rely on the carbon price shock series developed by Känzig (2023), which captures unexpected variations in emission allowance futures prices using high-frequency surprise changes. It is a monthly shock series that spans from 1999 to 2019. I aggregate the monthly carbon price shock series up to a quarterly frequency to match the frequency of the data. I estimate the effects using simple local projections:

$$y_{i,t+h} = \beta^i_{h,0} + \gamma^i_h \, CPShock_t + \sum_{\ell=1}^{p} \beta^i_{h,\ell} \, y_{i,t-\ell} + \delta^i_h \, t + \epsilon_{i,t,h}, \tag{1}$$

where $CPShock_t$ denotes the ETS carbon price shock series. The coefficient γ^i_h measures the response of variable i at horizon h to a carbon price shock. I include three lags of the dependent variable as controls ($p = 3$). The term $\delta^i_h t$ accounts for linear trends over the sample. The estimation is based on quarterly euro area data from 1999Q1 to 2019Q4, focusing on the impact of carbon price increases on prices, greenhouse gas emissions, and real activity. Specifically, I use the following set of variables:

The variables included in the local projections are HICP energy inflation, headline HICP inflation, HICP inflation excluding energy, the real fossil energy price, greenhouse gas (GHG) emissions, industrial energy production, the short-term policy rate, real GDP, real private consumption, real investment, real wages, and capacity utilization. The real fossil energy price is constructed as a weighted index of the Brent crude oil price and the HICP gas component, deflated by headline HICP. For the short-term policy rate, I splice the ECB policy rate with the shadow rate from Wu and Xia (2020) to account for the period when the policy rate was constrained by the zero lower bound. Since GHG emissions are only available annually, I construct a quarterly series using the Chow–Lin temporal disaggregation method with indicators, applying the code from Quilis (2024). Following Känzig (2023), I use the HICP energy component and industrial production as quarterly indicators. Inflation and the interest rate are expressed at annualized rates, while all other variables are in log-levels except for capacity utilization.

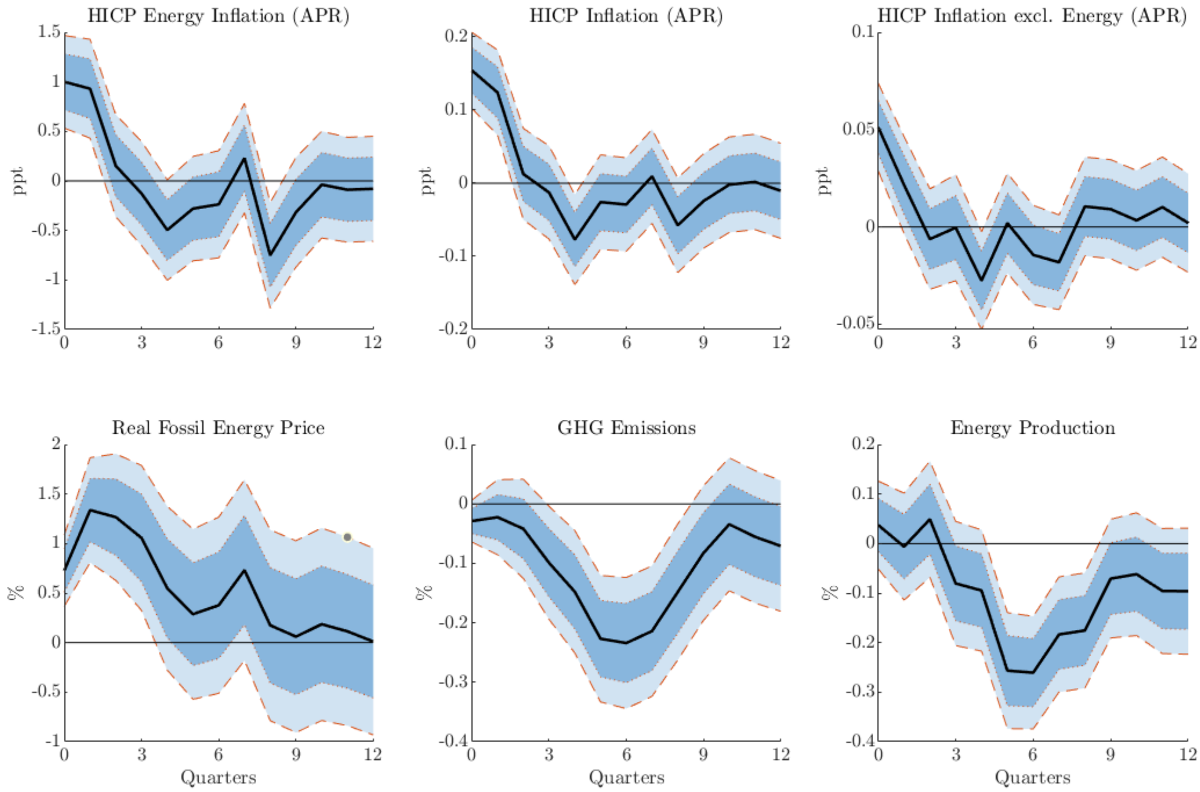

Figure 1: Impulse responses of prices, emissions and energy

The solid line is the point estimate, the dark and light shaded areas are 68 and 90 % confidence bands. The shock is normalized to increase annual energy inflation by 1 ppt.

Figure 1 shows the impulse responses to a carbon price shock for prices, GHG emissions, and industrial energy production. The shock is normalized to raise annualized energy inflation by one percentage point on impact, and confidence bands are computed using the lag-augmentation method of Montiel Olea and Plagborg-Møller (2021). The shock triggers an immediate rise in fossil energy prices and, consequently, aggregate energy prices. The pass-through of energy prices to consumer prices appears to be strong, as headline inflation increases by about 0.15 percentage points on impact. Inflation excluding energy also rises slightly, reflecting higher production costs being passed on to consumers. The carbon price increase proves effective in curbing emissions, with GHG emissions falling significantly by up to 0.25 percent. Interestingly, this adjustment does not occur immediately but unfolds gradually, with the peak reduction materializing only a year after the shock. A very similar pattern is observed for industrial energy production, which contracts in response to the shock along almost the same trajectory. This co-movement is intuitive, as a large share of emissions originates from the combustion of fossil fuels in energy production. When higher carbon prices make fossil-based generation more costly, industrial energy output declines, and emissions fall in tandem. The delayed adjustment suggests that the reduction in fossil energy use unfolds gradually, leading both series to peak only with a lag. In terms of both direction and magnitude, these results are consistent with Känzig (2023) as well as previous evidence on different energy price shocks, such as oil shocks (Känzig (2021), Baumeister and Hamilton (2019)).

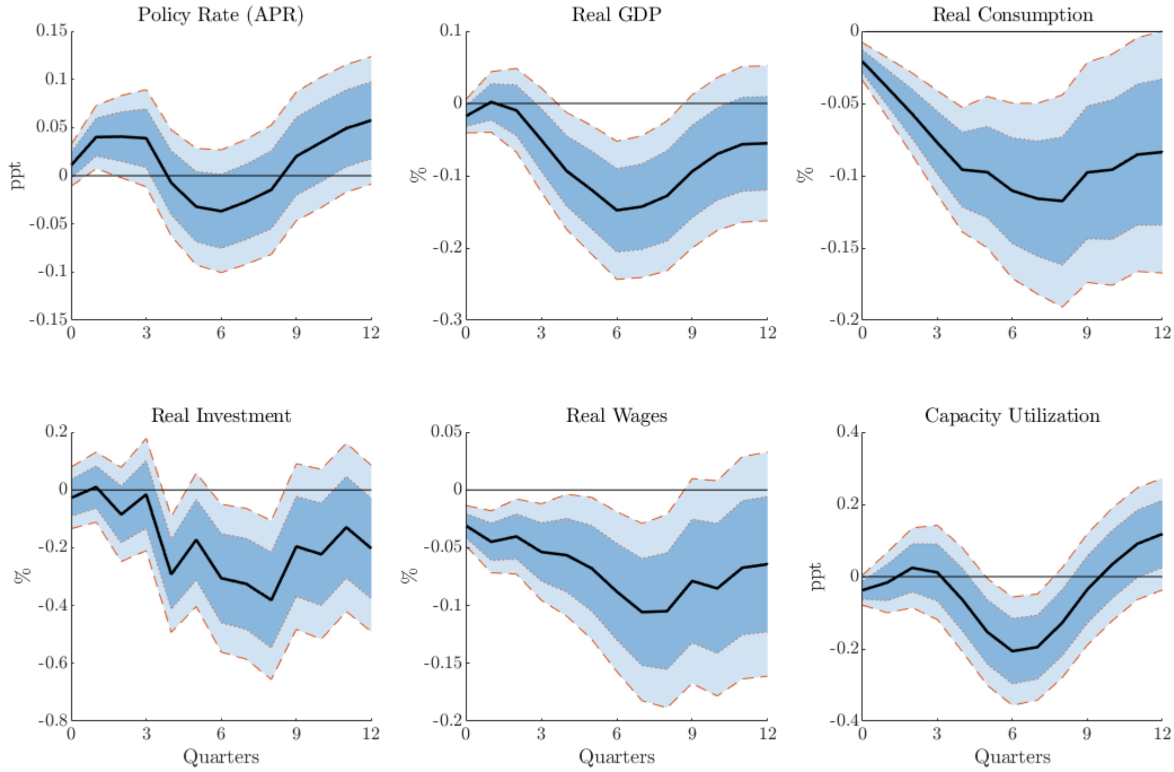

Figure 2: Impulse responses of macroeconomic aggregates

The solid line is the point estimate, the dark and light shaded areas are 68 and 90 % confidence bands. The shock is normalized to increase annual energy inflation by 1 ppt.

The results indicate a strong pass-through from fossil energy to consumer prices. Figure 2 presents the responses of several macroeconomic aggregates to the same carbon price shock. Real GDP declines significantly, with a peak reduction of about 0.15 percent, driven by contractions in both consumption and investment. Real wages and capacity utilization in production also fall. Higher energy prices directly reduce the disposable income of households and firms, lowering consumption and investment expenditure. This weakens output, which in turn creates incentives for firms to reduce labor costs. The delayed but significant decline in wages shown in Figure 2 illustrates this adjustment, and the resulting reduction in labor income further dampens aggregate demand. According to Känzig (2023), such indirect general equilibrium effects account for more than two-thirds of the aggregate decline in consumption, helping explain the strong response of the real economy to the carbon price shock. Contractionary monetary policy in reaction to inflationary pressures from higher energy prices represents another potential channel, although the estimated policy rate response is small and largely insignificant. The decline in capacity utilization suggests that firms scale back production in response to higher energy costs.

3 The Model

The macro-climate model is a two-agent New Keynesian (TANK) framework extended by an energy sector. The economy is populated by ricardian and hand-to-mouth households, final good producers, intermediate good producers as well as producers of green and fossil energy. The production of fossil energy generates carbon emissions, while green energy production is carbon-neutral. Environmental damage from carbon emissions negatively affects total factor productivity. A bundle of green and fossil energy is used for both intermediate goods production and final consumption of households. Carbon policy is modeled as a surcharge on the price of fossil energy.

3.1 Households

The model features two types of households: Ricardian agents, denoted by subscript R, and hand-to-mouth agents, denoted by subscript H. R agents perform intertemporal optimization, have access to financial markets and supply capital and labor. Their preferences are specified as:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \log(c_{t,R} - b c_{R,t-1}) - \frac{h_{t,R}^{1+\varphi}}{1+\varphi} \right\}, \tag{2}$$

where $c_{t,R}$ represents final consumption, $h_{t,R}$ represents hours worked, $\beta \in (0,1)$ is the discount factor, b controls the degree of habit formation and φ is the inverse Frisch elasticity.

The R household's budget constraint is defined as follows in nominal terms:

$$\sum_j P_{t,R} c_{t,R} + P_t^I i_t^j + B_{t+1} = W_t h_{t,R} + (R_t^{k,j} u_t^j - a(u_t^j) P_t^I) k_{t-1}^j + R_{t-1} B_t + T_{t,R} + \Pi_t. \tag{3}$$

Here, $P_{t,R}$ is the price of final consumption goods and P_t^I is the price of investment goods $i_t^j, j \in (Y, G, B)$. Investment is allocated across three different sectors: capital goods for intermediate goods production k_t^Y, green energy production k_t^G and fossil energy production k_t^B. R_t^k is the nominal rental rate of capital and $u_t^j K_t^j$ denotes the household's supply of capital services in the given period, where u_t^j is the capacity utilization rate. $a(u_t^j)$ denotes cost of capacity utilization in units of investment goods. R households can invest in one-period risk-free bonds B_{t+1}, where $R_{t-1}B_t$ denotes the revenue from holding bonds. $W_t h_{t,R}$ is household R' labor income, $T_{t,R}$ are lump-sum transfers directed towards R agents and Π_t are firm profits.

Following Christiano et al. (2005), R households face quadratic adjustment costs in investment, so that investment is smoothed over time. This results in the following capital law of motion for each sector:

$$k_t^j = (1-\delta)k_{t-1}^j + \left[1 - \frac{\kappa_I}{2}\left(\frac{i_t^j}{i_{t-1}^j} - 1\right)^2\right] i_t^j, \quad j \in (Y, G, B) \tag{4}$$

where κ_I denotes the investment adjustment cost parameter.

Labor supplied by individual households is differentiated, which yields the following expression for aggregate labor supply:

$$h_{t,R} = \left(\int_0^1 h_{t,R}(i)^{\frac{\varepsilon_W - 1}{\varepsilon_W}} di\right)^{\frac{\varepsilon_W}{\varepsilon_W - 1}}, \tag{5}$$

where ε_W is the elasticity of substitution between individual varieties.

Ricardian households are assumed to set wages in a Calvo-style staggered fashion. Each period household i is able to reoptimize its nominal wage rate with probability $1 - \theta_W$. The remaining fraction of households cannot reoptimize, such that $W_t(i) = W_{t-1}(i)$ with probability θ_W.

The second type of households are hand-to-mouth, meaning they do not perform intertemporal optimization and have no access to financial markets, but instead consume all their disposable income in a given period. Their budget constraint reads as follows:

$$P_{t,H} c_{t,H} = W_t h_{t,H} + T_{t,H},$$

where $T_{t,H}$ are transfer payments directed towards H households. For simplicity, I assume that H agents have no bargaining power and do not optimize their hours worked, but instead work the same hours as R agents, $h_{t,H} = h_{t,R}$ to earn economy-wide wage W_t following Erceg et al. (2024). Including hand-to-mouth agents is crucial to account for potentially large demand-side effects of energy price shocks (see Auclert et al. (2023), Chan et al. (2024), Känzig (2023)).

To capture the energy consumption of households, final consumption $c_{t,j}$ is modeled as a CES bundle of energy ($c_{t.j}^E$) and the manufactured good from final good production

$(c^X_{t,j})$, such that

$$c_{t,j} = \left(\gamma_{c,j}^{\frac{1}{\varrho_c}} (c^E_{t,j})^{\frac{\varrho_c - 1}{\varrho_c}} + (1-\gamma_{c,j})^{\frac{1}{\varrho_c}} (c^X_{t,j})^{\frac{\varrho_c - 1}{\varrho_c}} \right)^{\frac{\varrho_c}{\varrho_c - 1}}, \ j \in \{H, R\}. \tag{6}$$

Here, $\gamma_{c,j}$ determines the share of energy in final consumption, which is heterogeneous across household types, and ϱ_c is the elasticity of substitution between energy and the manufactured good. The resulting demand equations for energy and the manufactured consumption good are:

$$c^E_{t,j} = \gamma_{c,j} \left(\frac{P^E_t}{P_{t,j}} \right)^{-\varrho_c} c_{t,j}, \tag{7}$$

$$c^X_{t,j} = (1-\gamma_{c,j}) \left(\frac{P^X_t}{P_{t,j}} \right)^{-\varrho_c} c_{t,j}, \tag{8}$$

where P^E_t and P^X_t are their respective prices. The CPI can therefore be defined such that it captures both goods and energy prices:

$$P_{t,j} = \left(\gamma_{c,j} (P^E_t)^{1-\varrho_{c,j}} + (1-\gamma_c)(P^X_t)^{1-\varrho_c} \right)^{\frac{1}{1-\varrho_c}}. \tag{9}$$

This specification makes it possible to explicitly define a measure for core inflation π^X_t, which, in contrast to headline inflation π_t, excludes fluctuations in energy prices:

$$\pi^X_t = \frac{p^X_t}{p^X_{t-1}} \pi_t, \tag{10}$$

where p^X_t denotes the manufactured good price in terms of domestic CPI.
Similarly, energy inflation is defined as follows:

$$\pi^E_t = \frac{p^E_t}{p^E_{t-1}} \pi_t. \tag{11}$$

3.2 Final good firms

The representative final-good firm uses the following CES bundle to produce the final good y_t:

$$y_t = \left(\int_0^1 y_t(i)^{\frac{\varepsilon - 1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon - 1}}, \tag{12}$$

where $y_t(i)$ is an intermediate good produced by intermediate good firm i and ε is the elasticity of substitution between intermediate goods. The profit maximization problem of the final good firm reads as follows:

$$\max_{y_t,\{y_t(i)\}_{i\in[0,1]}} \quad P_t^X y_t - \int_0^1 P_t^X(i) y_t(i) di \tag{13}$$

$$\text{s.t.} \quad y_t = \left(\int_0^1 y_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right)^{\frac{\varepsilon}{\varepsilon-1}}. \tag{14}$$

Here, $P_{H,t}(i)$ is the price of the intermediate good produced by firm i in the home country. The problem yields the following intermediate input demand:

$$y_t(i) = \left(\frac{P_t^X(i)}{P_t^X}\right)^{-\varepsilon} y_t. \tag{15}$$

3.3 Intermediate good firms

A continuum of intermediate goods $y_t(i)$ is produced by price setting firms that are optimizing under monopolistic competition. The production function of these firms is a CES aggregator in energy and value added from a Cobb-Douglas bundle of capital and labor, following Hassler et al. (2021):

$$y_t(i) = A_t^Y \left[(1-\gamma_Y)^{\frac{1}{\varrho_Y}} \left((u_t^Y k_{t-1}^Y(i))^{\alpha} (h_t^Y(i))^{1-\alpha}\right)^{\frac{\varrho_Y-1}{\varrho_Y}} + (\gamma_Y)^{\frac{1}{\varrho_Y}} \left(e_t^Y(i)\right)^{\frac{\varrho_Y-1}{\varrho_Y}}\right]^{\frac{\varrho_Y}{\varrho_Y-1}}, \tag{16}$$

where $e_t^Y(i)$, $u_t^Y k_{t-1}^Y(i)$ and $h_t^Y(i)$ respectively is the energy, effective capital and labor demanded by firm i, α is the capital share in the value added from capital and labor, γ_Y is the energy share in intermediate goods production and ϱ_Y is the elasticity of substitution between energy and the capital-labor bundle.

Firms set their price P_t^X and choose input factors capital, labor and energy to maximize profits subject to their production technology (16) and the demand of the final good firm (15).The firms set prices in Calvo-style staggered contracts, such that each firm faces a constant probability $1-\theta_P$ of being able to adjust its price. The remaining firms that are not able to reoptimize set their price according to $P_t^X(i) = P_{t-1}^X(i)$.

3.4 Energy sector

A representative energy firm combines two different energy sources, green energy e_t^G and fossil energy e_t^F, to provide energy services to households and for intermediate goods production. The energy inputs are bundled using the following CES aggregator:

$$e_t = \left((1-\zeta)^{\frac{1}{\xi}} (e_t^G)^{\frac{\xi-1}{\xi}} + \zeta^{\frac{1}{\xi}} (e_t^F\ (1-\Gamma_t))^{\frac{\xi-1}{\xi}}\right)^{\frac{\xi}{\xi-1}}, \tag{17}$$

where ξ is the elasticity of substitution between green and fossil energy and ζ determines the share of fossil energy in energy production. The energy firm faces quadratic adjustment costs Γ_t in fossil energy:

$$\Gamma_t = \frac{\kappa_E}{2}\left(\frac{e_t^F}{e_{t-1}^F} - 1\right)^2. \tag{18}$$

These costs are crucial to account for the slow adjustment of fossil energy use following a carbon price increase, for instance due to long-term contracts with fossil fuel providers or the lack of appropriate infrastructure to switch to renewable energy sources.

The respective demand equations for fossil and green energy are:

$$e_t^F = \zeta\left(\frac{(1+\tau_t)p_t^F}{(1-\Gamma_t-\Gamma_t' e_t^F)p_t^E}\right)^{-\xi}\frac{e_t}{1-\Gamma_t}, \tag{19}$$

$$e_t^G = (1-\zeta)\left(\frac{p_t^G}{p_t^E}\right)^{-\xi} e_t, \tag{20}$$

where the carbon policy rate τ_t is modeled as a surcharge on the price of fossil energy. This implies a trade-off for energy firms. Higher carbon prices create an incentive for energy firms to reduce fossil fuel use to lower production costs. However, the firms face adjustment costs, preventing large and abrupt cuts in fossil energy use. I model carbon policy as a carbon tax for simplicity, because both carbon taxes and cap-and-trade systems like the EU ETS increase the price of fossil fuel use to reduce emissions. The carbon tax rate follows an AR(1) process:

$$\log(\tau_t) = (1-\rho_\tau)\log(\overline{\tau}) + \rho_\tau \log(\tau_{t-1}) + \epsilon_t^\tau, \tag{21}$$

where ϵ_t^τ is an exogenous carbon price shock and $\overline{\tau}$ is the steady state carbon tax rate.

Both energy inputs are produced using a Cobb-Douglas bundle of sector-specific capital and labor services k_t^j and h_t^j, $j \in \{F, G\}$:

$$e_t^j = A_t^j (u_t^j k_{t-1}^j)^\alpha (h_t^j)^{1-\alpha}, \quad j \in \{F, G\}, \tag{22}$$

where u_t^j is the sector-specific rate of capacity utilization.
Fossil energy production generates carbon emissions m_t, such that:

$$m_t = \vartheta e_t^F, \tag{23}$$

where ϑ determines the carbon content of fossil energy production.

3.5 Monetary and fiscal policy

The fiscal authority levies the carbon tax on energy firms and rebates the revenues to Ricardian households through lump-sum transfers. This provides a neutral benchmark for revenue use, consistent with the EU ETS, where revenues are intended either to finance environmental projects or to be returned to households, with allocation left to the discretion of member states. I abstract from the existence of public debt and assume the fiscal authorities run a balanced budget at all times. The government budget constraint takes the following form:

$$\tau_t p_t^B e_t^B = T_t + g, \tag{24}$$

where government spending g is assumed to be constant.

The central bank follows a Taylor rule to set the nominal interest rate r_t:

$$\frac{r_t}{r} = \left(\frac{r_{t-1}}{r}\right)^{\rho_r} \left[\left(\frac{\pi_t}{\pi}\right)^{\phi_\pi} \left(\frac{gdp_t}{gdp}\right)^{\phi_y}\right]^{(1-\rho_r)}, \tag{25}$$

In the baseline analysis, the central bank is assumed to respond to deviations in headline HICP inflation and GDP.

3.6 Climate change

I introduce a climate change externality as in Golosov et al. (2014) into my model to capture negative effects of increasing atmospheric carbon on the economy. The externality creates a two-way interaction between the economy and climate change. In the benchmark model, fossil energy production generates carbon emissions, which feed into the stock of atmospheric carbon. The stock of atmospheric carbon evolves according to the following process:

$$S_t = (1-\delta_S)S_{t-1} + (m_t + m^{row}), \tag{26}$$

where $\delta_{S,0}$ is the depreciation rate of carbon dioxide from the atmosphere and $\delta_{S,1}$ is the percentage of carbon emissions that enter the atmosphere. The global stock of atmospheric carbon is fueled by domestic euro area emissions m_t and emissions from the rest of the world m^{row}, which is constant over time, because I assume no climate policy action in the rest of the world.

The extended model now introduces a feedback effect, such that the environmental damage from higher atmospheric carbon reduces total factor productivity.[1]. Following Golosov et al. (2014), total factor productivity in each production sector is then modeled as follows:

$$A_t^i = a_t^i e^{-\psi_D S_t}, \qquad i \in \{Y, G, B\}, \tag{27}$$

where ψ_D is the damage parameter that determines the size of the externality and $a_t^i, i \in \{Y, G, B\}$ is the total factor productivity that would prevail in each sector without the environmental externality.[2]

3.7 Market clearing and functional forms

The labor and energy market clear such that:

$$h_t = h_t^Y + h_t^B + h_t^G, \tag{28}$$

$$e_t = \lambda c_{t,H}^E + (1-\lambda) c_{t,R}^E + e_t^Y, \tag{29}$$

where λ denotes the share of hand-to-mouth agents.
Aggregate investment is defined as follows:

$$i_t = i_t^Y + i_t^B + i_t^G. \tag{30}$$

Aggregating firm profits implies:

$$\Pi_t = \Pi_t^Y + \Pi_t^F + \Pi_t^G. \tag{31}$$

The resource constraint of the economy is then obtained by plugging the government budget constraint and the profit functions of intermediate goods firms and energy producers into the weighted sum of household budget constraints:

$$p_t^X y_t = p_t^X c_t^X + p_t^I i_t + p_t^X g + \sum_j a(u_t^j) k_{t-1}^j, \quad j \in \{Y, B, G\}. \tag{32}$$

Real GDP is measured as follows:

$$gdp_t = c_t + p_t^I i_t + p_t^X g, \tag{33}$$

[1]Antoher approach of some environmental DSGE models is to include the pollution externality directly into the utility function of households (see Acemoglu et al. (2012), Benmir et al. (2020), Barrage (2020)). However, Nordhaus (2008) and Heutel (2012) argue that such a modeling choice would be more appropriate for conventional pollutants that directly affect health rather than greenhouse gases.

[2]For simplicity, this is set to $a_t^i = 1$ in each sector.

where aggregate consumption is defined as:

$$c_t = \lambda c_{t,H} + (1-\lambda)c_{t,R}. \tag{34}$$

The capacity utilization adjustment cost function is defined as:

$$a(u) = \frac{1}{2}\sigma_0\sigma_a u^2 + \sigma_0(1-\sigma_a)u + \sigma_0\left(\frac{1}{2}\sigma_a - 1\right), \tag{35}$$

where σ_0 is set such that $a(1) = a'(1) = 0$ in steady state. The parameter σ_a controls the curvature of the adjustment cost function, such that a higher σ_a indicated larger costs for changing capacity utilization.

4 Estimation Results

I estimate the key parameters of the model by matching the dynamic responses to a carbon price shock in the model with the estimated impulse responses from the data presented in section 2 using Bayesian impulse response matching. First, I calibrate a set of parameters and then estimate the remaining parameters conditional on the set of calibrated parameters.

4.1 Estimation methodology

For the estimation I follow the limited information Bayesian methodology developed in Christiano et al. (2010) that minimizes the distance between the dynamic impulse responses to the carbon price shock ϵ_τ in the model and the analog responses in the data. The impulse responses from the data are estimated using local projections in section 2. I use ten of the variables considered in the local projections for the estimation procedure: real fossil energy prices, energy inflation, headline inflation, nominal interest rate, emissions, real GDP, real consumption, real investment, real wages and capacity utilization.

The estimation procedure relies on the assumption that the structural model correctly describes the data-generating process. Let θ_0 denote the true values of the model parameters, and let $\psi(\theta)$ represent the mapping from the parameter space to the model-implied impulse responses. Then, $\psi(\theta_0)$ corresponds to the true impulse responses, which are estimated from the data as $\hat{\psi}$. Under standard asymptotic sampling theory, when the number of observations T is large, the empirical impulse responses satisfy:

$$\sqrt{T}\left(\hat{\psi} - \psi(\theta_0)\right) \overset{d}{\sim} N(0, W(\theta_0, \zeta_0)). \tag{36}$$

Here, θ_0 represents the true values of the model parameters, while ζ_0 denotes the true values of shocks that are not explicitly estimated. The vector $\hat{\psi}$ includes the contemporaneous and 11 lagged responses of the 10 variables used for the estimation. The asymptotic distribution of $\hat{\psi}$ can be rewritten as:

$$\hat{\psi} \overset{d}{\sim} N(\psi(\theta_0), V), \tag{37}$$

where $V = W(\theta_0, \zeta_0)/T$. In practice, I use a consistent estimator for V, considering only diagonal elements, as suggested by Christiano et al. (2010).

To estimate the model parameters, I treat $\hat{\psi}$ as observed data and specify prior distributions for θ. Using Bayes' theorem, I compute the posterior distribution of θ given $\hat{\psi}$ and V. The likelihood function for $\hat{\psi}$ given θ is approximated by:

$$f(\hat{\psi}|\theta, V) = (2\pi)^{-N/2}|V|^{-1/2} \exp\left[-0.5(\hat{\psi} - \psi(\theta))' V^{-1}(\hat{\psi} - \psi(\theta))\right]. \tag{38}$$

Maximizing this function provides an approximate maximum likelihood estimator for θ. The likelihood function is derived from the asymptotic distribution of the impulse responses and accounts for estimation uncertainty. I obtain parameter estimates by maximizing the posterior density and use a Markov Chain Monte Carlo (MCMC) algorithm to sample from the posterior distribution.

4.2 Calibrated parameters

The model is calibrated to the euro area at a quarterly frequency. All calibrated parameter values are shown in Table 1.

Table 1: Calibrated parameters

Parameter	Description	Value	Source
$(p^E c_{e,R})/(p_R c_R)$	Energy share in consumption R	0.07	Eurostat, HFCS (2015)
$(p^E c_{e,H})/(p_H c_H)$	Energy share in consumption H	0.16	Eurostat, HFCS (2015)
$(p^E e^Y)/(p^C y)$	Energy share in production	0.07	Coenen et al. (2024)
e^G/e	Green energy share	0.15	Eurostat
β	Discount factor	0.995	Annual real rate 2%
φ	Inverse Frisch elasticity	1	Standard value
α	Capital share in production	0.3	Standard value
δ	Depreciation rate	0.025	Standard value
μ_P	Gross st.-st. price mark-up	1.2	Standard value
μ_W	Gross st.-st. wage mark-up	1.2	Standard value
δ_S	Decay atmospheric carbon	0.9983	Hassler et al. (2020)
$100 \cdot \psi_D$	Damage coefficient	0.002698	Hassler et al. (2020)

The quarterly discount factor is set to $\beta = 0.995$, which implies an annual steady-state real interest rate of 2%. The steady-state inflation rate is calibrated to match an annual inflation of 2% for both core and headline inflation. The substitution elasticity between intermediate goods is set to $\varepsilon = 6$, which is a standard value in New Keynesian models, implying a gross steady-state price mark-up of $\mu_P = \frac{\varepsilon}{\varepsilon - 1} = 1.2$. The gross steady-state wage mark-up is also set to $\mu_W = 1.2$. The capital share in production is set to $\alpha = 0.3$ and capital depreciates at a rate of $\delta = 2.5\%$ each quarter. The inverse Frisch elasticity is set to $\varphi = 1$.

The energy-related parameters are calibrated to match euro area data in steady state. The share of energy in the consumption bundle, $\omega^j_{e,c}$ for $j \in R, H$, is set to replicate households' energy expenditure shares in the euro area. According to Eurostat, these shares are about 16 percent for households in the bottom income quartile and 7 percent for the remaining households. This calibration implies an economy-wide average energy expenditure share of roughly 9 percent, which is consistent with the HICP weight for energy. The distribution parameter $\gamma_{c,j}$ is then calibrated to ensure this expenditure share of every value of p^E and ϱ_c in steady state:

$$\gamma_{c.j} = \omega^j_{e,c} (p^E)^{\varrho_c - 1}. \tag{39}$$

Similarly, $\omega_{e,y}$ matches the share of energy in production of about 7% in the euro area following Coenen et al. (2024). such that:

$$\gamma_c = \omega_{e,y} \left(\frac{p^E}{p^X} \right)^{\varrho_y - 1}. \tag{40}$$

The steady-state share of green energy in aggregate energy production is set to $\zeta = 15\%$, reflecting the average value for the euro area for the sample period of 1999 to 2019.

Finally, for the calibration of the climate module, I follow the estimates from Hassler et al. (2020). The damage function coefficient ψ_D is estimated to specifically capture damages from carbon-induced temperature increases in Europe.

4.3 Estimated parameters and results

Conditional on the calibrated parameters, I then estimate the remaining fifteen model parameters. Table 2 reports the prior and posterior distributions of the estimated parameters. This section discusses the estimated parameter values and their implications, with a particular focus on the energy-related parameters.

First, the results imply strong complementarity between energy and other inputs in production as well as energy and non-energy goods in consumption. This complementarity is a standard assumption in macro climate models with energy with values usually ranging between 0.2 and 0.5 (Hassler et al. (2021), Coenen et al. (2024), Diluiso et al. (2021)). My estimates are lie slightly below this range with $\varrho_c = 0.12$ and $\varrho_y = 0.07$. The 90% interval is also on the lower end of estimates in the literature. Such a high degree of complementarity makes households and firms very vulnerable to carbon price

Table 2: Priors and Posteriors of Parameters

Parameter	Prior	Posterior	
	$\mathcal{D}$, Mode [5-95%]	Mode	[5-95%]
Energy complementarity firms, ϱ_y	$\mathcal{G}$, 0.32 [0.13 1.07]	**0.07**	[0.02 0.20]
Energy complementarity households, ϱ_c	$\mathcal{G}$, 0.32 [0.13 1.07]	**0.12**	[0.04 0.29]
Substitution green and fossil energy, ξ	$\mathcal{U}$, – [0.2 3.8]	**0.38**	[0.23 0.72]
Fossil energy adjustment cost, κ_E	$\mathcal{U}$, – [1.5 28.5]	**10.1**	[6.4 16.3]
Share of hand-to-mouth agents, λ	$\mathcal{B}$, 0.28 [0.15 0.48]	**0.25**	[0.16 0.39]
Habit persistence, b	$\mathcal{B}$, 0.63 [0.34 0.83]	**0.73**	[0.43 0.88]
Calvo wage stickiness, θ_w	$\mathcal{B}$, 0.76 [0.43 0.92]	**0.84**	[0.60 0.96]
Investment adjustment costs, κ_I	$\mathcal{G}$, 3.20 [1.27 10.73]	**3.65**	[0.28 8.50]
Capacity utilization adj. costs, κ_U	$\mathcal{G}$, 0.44 [0.15 2.46]	**0.22**	[0.03 1.02]
Calvo price stickiness, θ_p	$\mathcal{B}$, 0.76 [0.43 0.92]	**0.61**	[0.35 0.81]
Taylor rule inflation coeff., ϕ_π	$\mathcal{G}$, 1.58 [1.36 1.84]	**1.53**	[1.25 1.88]
Taylor rule output coeff., ϕ_y	$\mathcal{G}$, 0.04 [0.01 0.26]	**0.04**	[0.00 0.15]
Interest rate smoothing, ρ_r	$\mathcal{B}$, 0.85 [0.61 0.94]	**0.95**	[0.90 0.99]
Autocorr. carbon shock, ρ_τ	$\mathcal{B}$, 0.75 [0.44 0.95]	**0.90**	[0.85 0.95]
Std.Dev. carbon shock, σ_τ	$\mathcal{IG}$, 0.07 [0.04 0.56]	**0.26**	[0.21 0.35]

Notes: Posterior mode and intervals are based on a standard MCMC algorithm with 500,000 draws (5 chains, 50% burn-in, acceptance rate about 27%). $\mathcal{B}, \mathcal{G}, \mathcal{U}, \mathcal{IG}$ denote beta, gamma, uniform and inverse-gamma distributions, respectively.

shocks, because the sharp increase in energy prices will increase their energy bills, leading to a significant drop in consumption and investment expenditure. These results are in line with Gagliardone and Gertler (2023) who estimate strong complementarities of oil in production and consumption using an oil price shock.

Second, the posterior mode of the substitution elasticity between green and fossil energy is estimated at $\xi = 0.38$. Since this value is well below unity, it implies that green and fossil energy behave as complements rather than substitutes in aggregate energy production. The 90% confidence interval places an upper bound at 0.72, reinforcing the conclusion that the two inputs are complements. Standard values in the literature typically range from 1.8 to 3, suggesting much higher substitutability (Papageorgiou et al. (2017), Coenen et al. (2024)). The relatively low estimate obtained here reflects that the identification strategy captures a short-term substitution elasticity following temporary carbon price shocks, rather than long-term adjustment dynamics in response to permanent carbon price increases. The substitution elasticity remains a key parameter for assessing the effectiveness of carbon pricing policies.

Third, the posterior mode of the fossil energy adjustment cost parameter is significantly positive with $\kappa_E = 10.1$. These types of adjustment costs are non-standard in New Keynesian climate models, implying a value of $\kappa_E = 0$. My results suggest that including adjustment costs in the share of fossil energy is crucial to match the lagged response of emissions following an increase in the carbon price. Section 4.4 provides a detailed analysis of the implications of the parameter estimates for ξ and κ_E.

Finally, the estimated posterior mode of the population share of hand-to-mouth households is $\lambda = 0.25$. This indicates that accounting for hand-to-mouth households is important in order to match the observed response of the economy to the shock. The estimate is also consistent with previous findings for the euro area (Dossche et al. (2021)).

The remaining parameters, that are not directly related to the energy sector, fall within a reasonable range for standard macroeconomic models. The degree of price stickiness suggests that prices are adjusted every three quarters on average, while nominal wages remain unchanged for about eight quarters on average. Habit persistence $b = 0.73$ is slightly higher, but still close to the estimate of the New Area Wide Model (Coenen et al. (2018), henceforth NAWM II). Investment and capacity utilization adjustment costs are a little lower than suggested by the NAWM II. The estimated Taylor rule coefficients suggest a high degree of interest rate smoothing and a small coefficient on output growth, while the output gap coefficient is close to zero, which is also in line with the NAWM II. The persistence of the carbon price shock is approximately $\rho_\tau = 0.9$.

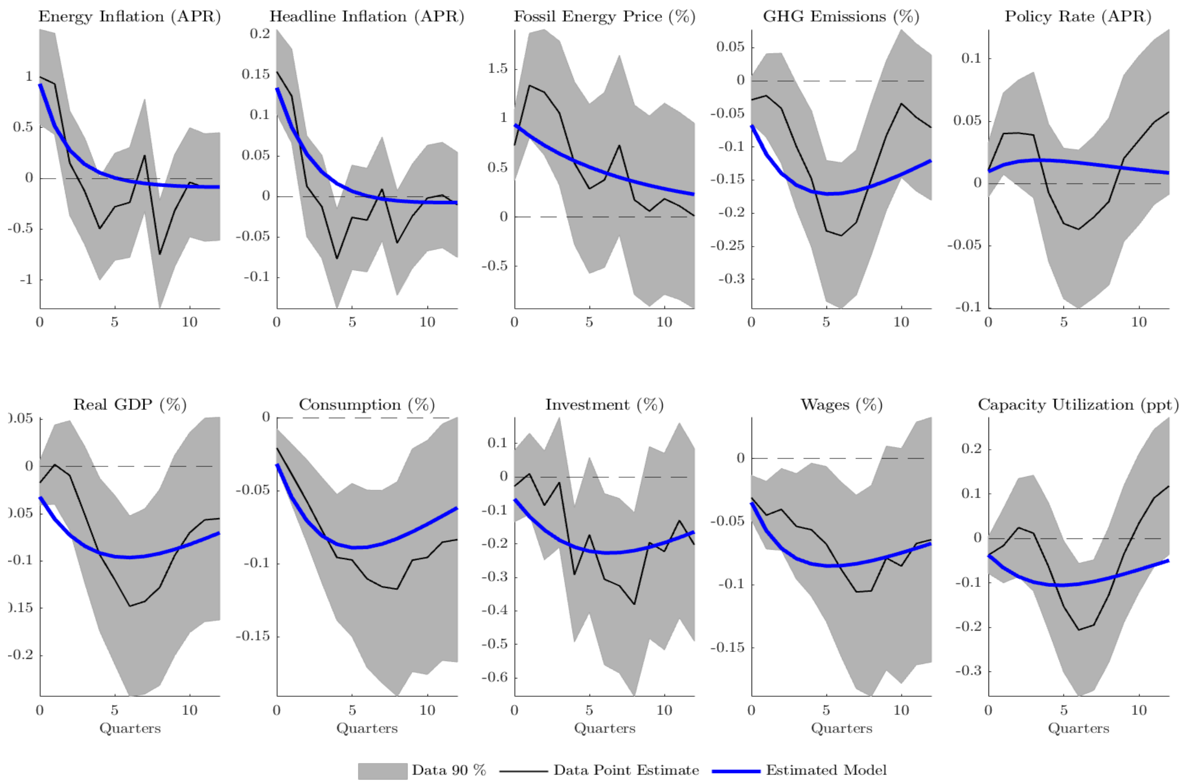

Figure 3: Impulse responses to carbon price shock: Model vs. Data

Figure 3 compares the dynamic impulse responses from the model, depicted by the blue line, to the responses estimated from the data in section 2, depicted by the black line. The grey areas are the 90% confidence intervals from the local projections. The model adequately captures the dynamics observed in the data following a carbon price shock. As aggregate energy prices are a bundle of fossil and green energy prices, the carbon price increase leads to a surge in energy inflation. This leads to a rise in headline inflation, both due to a direct increase in households' energy expenditure and due to firms passing on higher production costs to consumers. Higher energy bills directly lead to lower consumption and investment expenditure. The increase in production costs of firms leads to a decline in wages and capacity utilization. Lower wages in turn further decrease aggregate demand. The negative effects on aggregate demand are amplified by the rise in real interest rates as monetary policy leans against inflationary pressures.

4.4 Counterfactual analysis

This section highlights the the crucial role of two key parameters—the substitution elasticity between green and fossil energy ξ and the fossil energy adjustment cost parameter κ_E in accurately capturing the economy's response to a carbon price shock. These parameters govern how flexibly firms and households can adjust their energy consumption and how smoothly the economy transitions away from fossil energy in response to policy changes. To demonstrate how these two parameters are identified, I fix all estimated model parameters at their posterior mode (as reported in table 2) and simulate two counterfactual scenarios: (i) the absence of fossil energy adjustment costs ($\kappa_E = 0$) (ii) higher substitutability between green and fossil energy ($\xi = 3$). Figure 4 compares the resulting impulse responses to the baseline responses in figure 3.

Scenario (i) is depicted by the dashed red line. The most pronounced effect is observed in aggregate energy prices, with energy inflation surging over 3 percentage points on impact, which is more than three times the estimated response from the data. This short-run spike in energy prices transmits directly to headline inflation, which rises by 0.4 percentage points on impact, amplifying the economy-wide cost pressures. Consequently, household real income declines sharply, as higher energy prices directly increase energy expenditures. The resulting strong demand contraction prevents the model from capturing the more gradual decline in consumption observed in the data. Furthermore, since firms can immediately substitute away from fossil energy, emissions drop sharply on impact. However, this implies that the model fails to reproduce the observed gradual decline in emissions following a carbon price shock. In reality, infrastructure limitations, supply constraints, and technological adoption barriers slow the transition away from fossil fuels, making the emission response less immediate and more persistent.

The dash-dotted yellow line depicts scenario (ii). A higher value for ξ implies that energy producers can more easily substitute away from fossil energy, which mutes the strong impact response of aggregate energy inflation. Consequently, the surge in headline inflation is notably dampened, easing the burden of higher energy costs on households. This results in a considerably smaller contraction in consumption compared to the base-

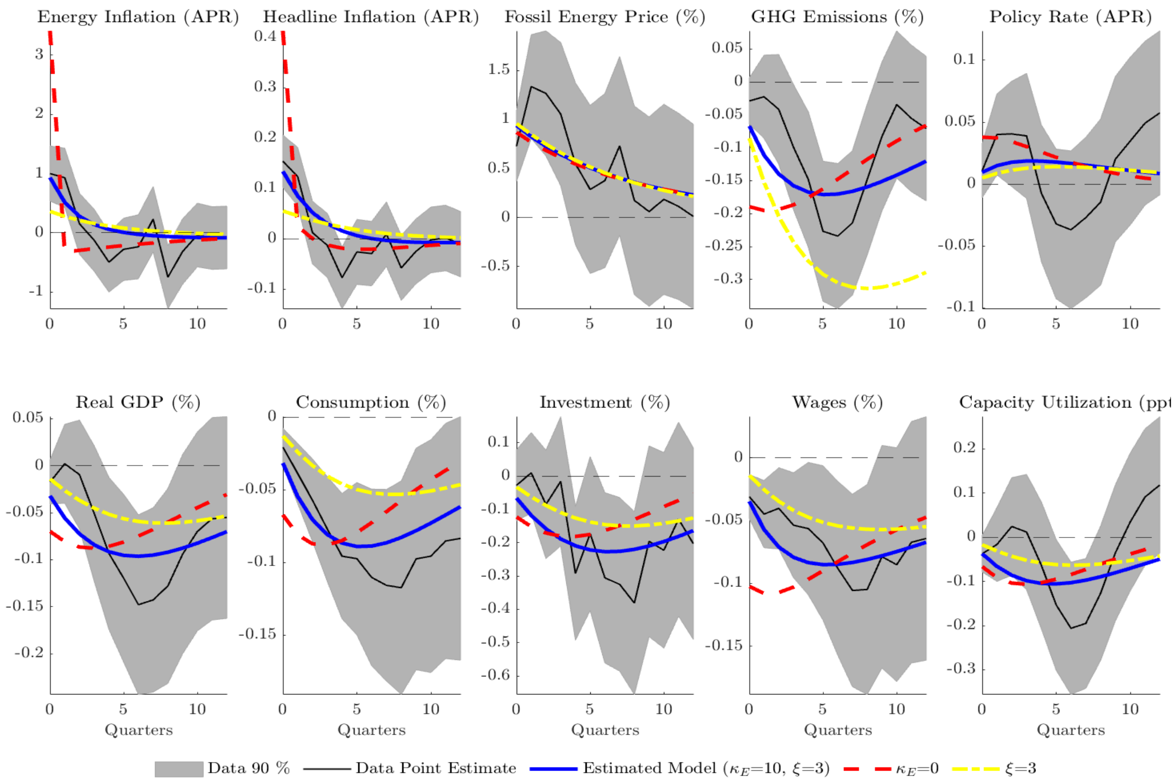

Figure 4: Impulse responses to carbon price shock: Counterfactual analysis

line estimated model. Additionally, greater substitutability accelerates the transition to green energy, leading to a more pronounced decline in emissions than observed in the data following a carbon price shock.

5 Monetary Policy

While central banks do not directly engage in climate change mitigation, they must respond to the macroeconomic consequences of carbon pricing. As shown above, a carbon price shock raises inflation while reducing output, creating a monetary policy trade-off.[3] This section examines the optimal monetary policy response to such a shock and compares how alternative policy rules shape the transmission of carbon pricing to the macroeconomy.

In the optimal policy regime, the central bank acts as a benevolent planner that chooses the optimal trajectory of the nominal interest rate $\{r_t\}$ to maximize social welfare

[3] This trade-off can also be observed empirically. Figure 6 in the Appendix shows no significant response of potential output to the shock, while the output gap and real GDP react in a very similar way in terms of direction and magnitude.

from a timeless perspective:

$$\max \mathcal{W}_{\prime} = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\lambda(\mathcal{U}_t^H) + (1-\lambda)(\mathcal{U}_t^R) \right], \tag{41}$$

subject to the private sector constraints from the firm's profit maximizing and household's utility maximizing behavior and the path of the carbon price. The central bank is assumed to commit to the contingent policy rule announced at time 0, which allows dynamic adjustment of the policy instrument to changing economic conditions. Note that I consider a second-best allocation as in Schmitt-Grohé and Uribe (2004) due to inefficiency in the initial steady state, arising from distortive monopolistic competition in intermediate-goods production and wage setting.

In addition, to assess the implications of an alternative interest rate rule, I analyze the implications of a policy rule that focusses on stabilizing core inflation π_t^X instead of headline inflation:

$$\frac{r_t}{r} = \left(\frac{r_{t-1}}{r}\right)^{\rho_r} \left[\left(\frac{\pi_t^X}{\pi}\right)^{\phi_\pi} \left(\frac{gdp_t}{gdp}\right)^{\phi_y} \right]^{(1-\rho_r)}. \tag{42}$$

The reaction coefficients in this specification are the same as in the baseline estimated model.

Figure 5 compares the impulse responses to a carbon price shock in the baseline estimated model to the two alternative monetary policy regimes. The optimal policy response to a carbon price shock differs markedly from the baseline Taylor rule that targets headline inflation. The Ramsey planner places substantial weight on stabilizing output rather than fully offsetting the rise in prices. While the shock raises headline inflation, it also generates a sharp contraction in GDP and consumption. These output losses arise because energy is a critical input across the economy: fossil and green energy are not easily substitutable in energy production, energy itself enters production of intermediate goods in a complementary way, and households have limited scope to substitute energy use in consumption. As a result, higher fossil energy prices translate into higher costs for households and firms, which leads to lower labor demand, and suppressed wages, which in turn reduce disposable income. In this environment, an aggressive interest rate increase to contain inflation would amplify the fall in demand and lead to larger welfare losses.

Instead, the planner cuts the policy rate sharply, thereby strongly mitigating the fall in output and consumption. This comes at the cost of temporarily higher headline and core inflation. In other words, the planner accepts inflationary pressures, focusing instead on stabilizing aggregate demand. The sharp initial interest rate cut is strongly driven by the significant fall in hand-to-mouth consumption in response to the shock. As hand-to-mouth households spend a relatively larger fraction of their disposable income on energy

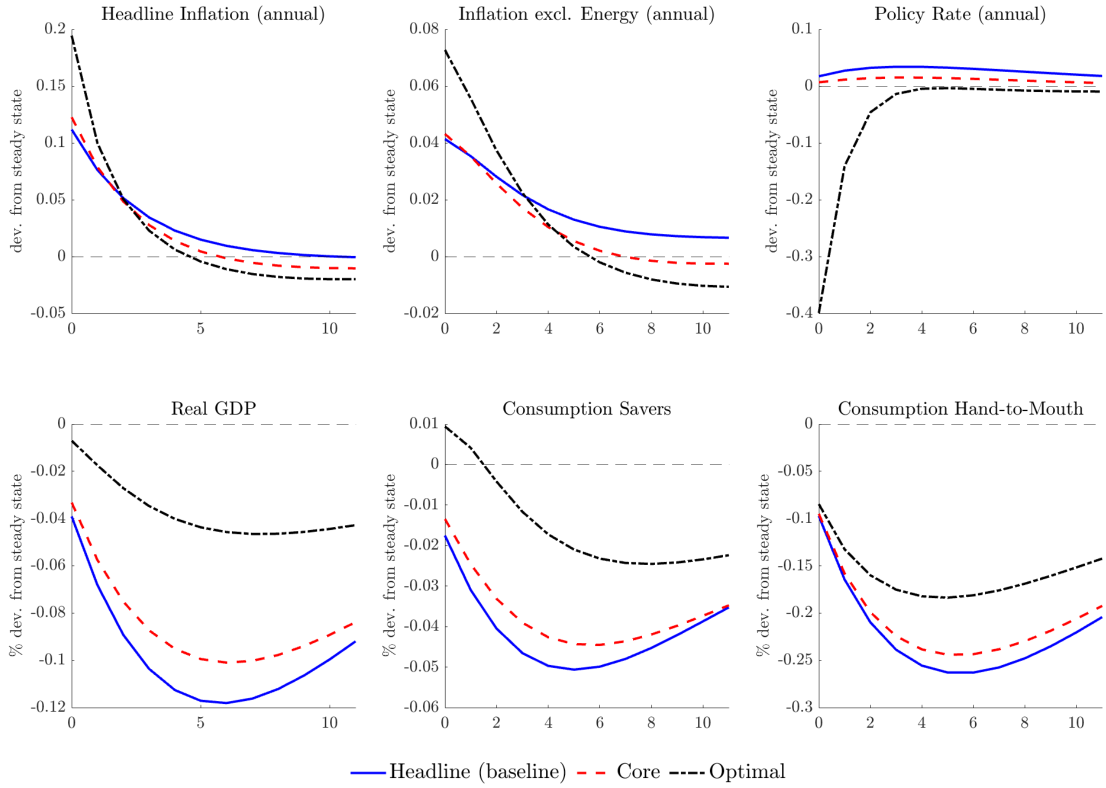

Figure 5: Impulse responses to a carbon price shock: Optimal monetary policy vs. headline inflation stabilization vs. core inflation stabilization

and cannot self-insure against adverse shocks, they are hit substantially harder by the shock than Ricardian households. Figure 7 in the Appendix shows that if the planner only maximizes welfare based on Ricardian agents' utility, the interest rate trajectory is much smoother. However, the planner in this scenario still clearly favors output stabilization over inflation stabilization.

When monetary policy follows a rule that targets core rather than headline inflation, the results come closer to the optimal response. Because core inflation excludes volatile energy prices, the central bank reacts less aggressively to the initial rise in headline inflation. This moderates the rise in real interest rates and thereby the contraction in output and consumption relative to the headline-based rule. While this comes at the cost of a slightly stronger initial increase in headline inflation, this effect is very small. In this sense, a core inflation rule approximates the Ramsey allocation more closely, as it implicitly places less weight on energy-driven price movements and thereby more on stabilizing the real economy, while not strongly increasing inflation volatility.

Overall, these results highlight that monetary policy faces a clear trade-off in responding to carbon price shocks. Policies that mechanically target headline inflation risk exacerbating inefficient output losses, while approaches that give less weight to energy-driven price fluctuations—such as core inflation targeting—deliver outcomes more in line with the welfare-maximizing solution.

6 Conclusion

In this paper, I develop and estimate a TANK macro-climate model that successfully captures the macroeconomic effects of carbon price shocks in the euro area. Using local projections, I document three key empirical responses to carbon price increases: a gradual decline in emissions, a sharp rise in headline inflation, and a significant drop in economic activity. To replicate these dynamics, I introduce two non-standard features into the model, fossil energy adjustment costs and low substitutability between green and fossil energy, both of which are essential for matching the observed responses. The estimated model closely aligns with the data, providing a robust empirical framework for analyzing the economic trade-offs of carbon pricing. With this empirically grounded framework, I assess the role of monetary policy in shaping macroeconomic outcomes following carbon price shocks. My results show that a welfare-maximizing planner prioritizes stabilizing real activity at the cost of temporarily higher inflation. A central bank focusing on core rather than headline inflation can mitigate GDP losses following a carbon price shock, thereby approximating the optimal policy response. These insights contribute to the macro-climate modeling literature by providing a framework that accurately captures the macroeconomic effects of carbon policy. As carbon pricing becomes an increasingly central policy tool, models that accurately reflect these dynamics will be essential for designing effective economic and monetary policies.

References

Acemoglu, Daron, Philippe Aghion, Leonardo Bursztyn, and David Hemous (2012). "The environment and directed technical change". In: *American economic review* 102.1, pp. 131–166.

Annicchiarico, Barbara and Fabio Di Dio (2015). "Environmental policy and macroeconomic dynamics in a new Keynesian model". In: *Journal of Environmental Economics and Management* 69, pp. 1–21.

Auclert, Adrien, Hugo Monnery, Matthew Rognlie, and Ludwig Straub (2023). *Managing an energy shock: Fiscal and monetary policy.* Tech. rep. National Bureau of Economic Research.

Barrage, Lint (2020). "Optimal dynamic carbon taxes in a climate–economy model with distortionary fiscal policy". In: *The Review of Economic Studies* 87.1, pp. 1–39.

Baumeister, Christiane and James D Hamilton (2019). "Structural interpretation of vector autoregressions with incomplete identification: Revisiting the role of oil supply and demand shocks". In: *American Economic Review* 109.5, pp. 1873–1910.

Benmir, Ghassane, Ivan Jaccard, and Gauthier Vermandel (2020). *Green asset pricing.* Tech. rep. ECB Working Paper No. 2477.

Chan, Jenny, Sebastian Diz, and Derrick Kanngiesser (2024). "Energy prices and household heterogeneity: Monetary policy in a gas-tank". In: *Journal of Monetary Economics* 147, p. 103620.

Christiano, Lawrence J, Martin Eichenbaum, and Charles L Evans (2005). "Nominal rigidities and the dynamic effects of a shock to monetary policy". In: *Journal of political Economy* 113.1, pp. 1–45.

Christiano, Lawrence J, Mathias Trabandt, and Karl Walentin (2010). "DSGE models for monetary policy analysis". In: *Handbook of monetary economics*. Vol. 3. Elsevier, pp. 285–367.

Coenen, Günter, Peter Karadi, Sebastian Schmidt, and Anders Warne (2018). "The New Area-Wide Model II: an extended version of the ECB's micro-founded model for forecasting and policy analysis with a financial sector". In.

Coenen, Günter, Matija Lozej, and Romanos Priftis (2024). "Macroeconomic effects of carbon transition policies: an assessment based on the ECB's New Area-Wide Model with a disaggregated energy sector". In: *European Economic Review* 167, p. 104798.

Del Negro, Marco, Julian Di Giovanni, and Keshav Dogra (2023). "Is the Green Transition Inflationary?" In: *FRB of New York Staff Report* 1053.

Diluiso, Francesca, Barbara Annicchiarico, Matthias Kalkuhl, and Jan C Minx (2021). "Climate actions and macro-financial stability: The role of central banks". In: *Journal of Environmental Economics and Management* 110, p. 102548.

Dossche, Maarten, Jiri Slacalek, and Guido Wolswijk (2021). "Monetary policy and inequality". In: *Economic Bulletin Articles* 2.

Erceg, Christopher, Marcin Kolasa, Jesper Lindé, and Andrea Pescatori (2024). "Can Energy Subsidies Help Slay Inflation?" In.

Gagliardone, Luca and Mark Gertler (2023). "Oil prices, monetary policy and inflation surges". In.

Golosov, Mikhail, John Hassler, Per Krusell, and Aleh Tsyvinski (2014). "Optimal taxes on fossil fuel in general equilibrium". In: *Econometrica* 82.1, pp. 41–88.

Hassler, John, Per Krusell, and Conny Olovsson (2021). "Directed technical change as a response to natural resource scarcity". In: *Journal of Political Economy* 129.11, pp. 3039–3072.

Hassler, John, Per Krusell, Conny Olovsson, and Michael Reiter (2020). "On the effectiveness of climate policies". In: *IIES WP* 53, p. 54.

Heutel, Garth (2012). "How should environmental policy respond to business cycles? Optimal policy under persistent productivity shocks". In: *Review of Economic Dynamics* 15.2, pp. 244–264.

Känzig, Diego R (2021). "The macroeconomic effects of oil supply news: Evidence from OPEC announcements". In: *American Economic Review* 111.4, pp. 1092–1125.

— (2023). *The unequal economic consequences of carbon pricing.* Tech. rep. National Bureau of Economic Research.

Konradt, Maximilian and Beatrice Weder di Mauro (2023). "Carbon taxation and greenflation: Evidence from europe and canada". In: *Journal of the European Economic Association*, jvad020.

Metcalf, Gilbert E and James H Stock (2023). "The macroeconomic impact of Europe's carbon taxes". In: *American Economic Journal: Macroeconomics* 15.3, pp. 265–286.

Montiel Olea, José Luis and Mikkel Plagborg-Møller (2021). "Local projection inference is simpler and more robust than you think". In: *Econometrica* 89.4, pp. 1789–1823.

Nakov, Anton and Carlos Thomas (2023). "Climate-conscious monetary policy". In.

Nordhaus, William (2008). *A question of balance: Weighing the options on global warming policies.* Yale University Press.

Olovsson, Conny and David Vestin (2023). *Greenflation?* Sveriges Riksbank.

Papageorgiou, Chris, Marianne Saam, and Patrick Schulte (2017). "Substitution between clean and dirty energy inputs: A macroeconomic perspective". In: *Review of Economics and Statistics* 99.2, pp. 281–290.

Quilis, Enrique M. (2024). *Temporal Disaggregation.* Accessed: 30 Oct. 2024. URL: https://de.mathworks.com/matlabcentral/fileexchange/69800-temporal-disaggregation.

Sahuc, Jean-Guillaume, Frank Smets, and Gauthier Vermandel (2025). "The New Keynesian Climate Model". In.

Schmitt-Grohé, Stephanie and Martin Uribe (2004). *Optimal operational monetary policy in the Christiano-Eichenbaum-Evans model of the US business cycle.*

Schnabel, Isabel (2022). *A new age of energy inflation: climateflation, fossilflation and greenflation.* Speech by Isabel Schnabel, Member of the Executive Board of the ECB, at a panel on "Monetary Policy and Climate Change" at The ECB and its Watchers XXII Conference. URL: https://www.ecb.europa.eu/press/key/date/2022/html/ecb.sp220317_2~dbb3582f0a.en.html.

Wu, Jing Cynthia and Fan Dora Xia (2020). "Negative interest rate policy and the yield curve". In: *Journal of Applied Econometrics* 35.6, pp. 653–672.

A Additional Figures

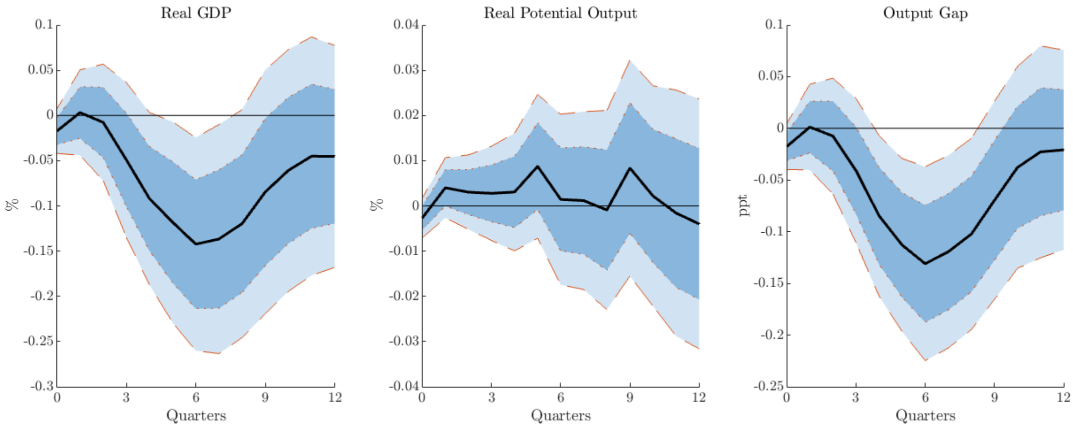

Figure 6: Impulse responses of potential output and the output gap
The solid line is the point estimate, the dark and light shaded areas are 68 and 90 % confidence bands. The shock is normalized to increase annual energy inflation by 1 ppt.

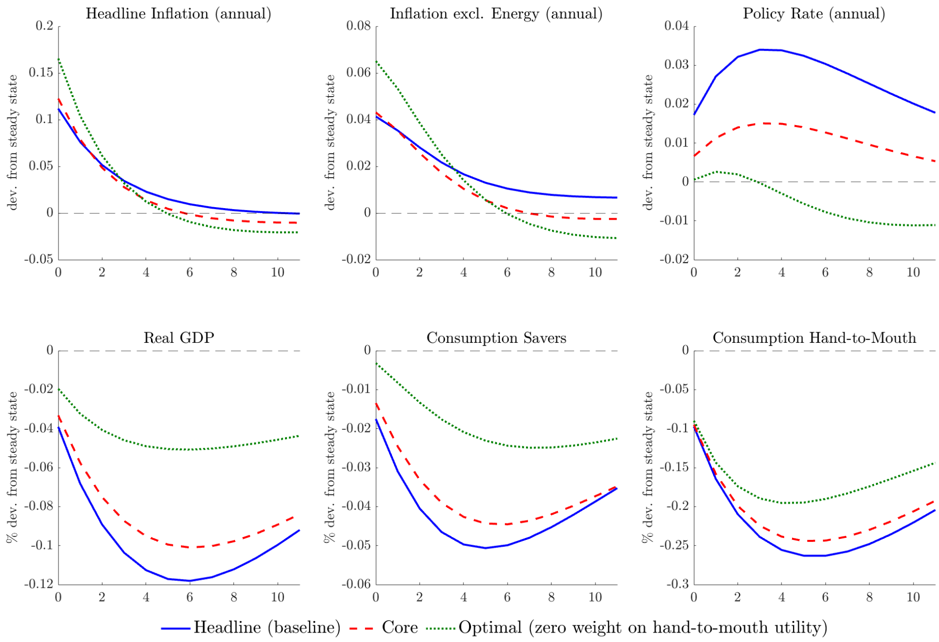

Figure 7: Impulse responses to a carbon price shock: Optimal monetary policy vs. headline inflation stabilization vs. core inflation stabilization